THE EFFECTS OF PRACTICE IN ITS INITIAL STAGES IN LIFTED WEIGHT EXPERIMENTS AND ITS BEARING UPON ANTHROPO-METRIC MEASUREMENTS

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In an earlier study[1] we found, by treating our results by the coefficient of divergence, that there was some factor which changed during the experimentation. A further statistical treatment, as well as the fact that the influence of this factor was greater upon a subject who was untrained at the beginning of experimentation than upon a trained one, led us to believe that this influence was due to the effect of the progressive practice which the subject obtained during the experimentation. We also found that the influence was greater at the beginning of the experiment.

Urban[2] takes up this problem by a consideration of his earlier results in lifted weight experiments, as well as a consideration of my results. Urban calculates the results which were taken according to the procedure of the method of constant stimuli in groups of 50 judgments upon each comparison pair. He studies the effect of this progressive practice upon the coefficients of precision (the h's of the psychometric functions), upon both the upper and lower thresholds, and upon the values of the interval of uncertainty and the point of subjective equality. He finds that the values of the h's for both the greater and the less judgments tend to increase. This increase is, in the early stages of practice, at first very rapid, and then proceeds relatively more slowly. The size of the interval of uncertainty tends to grow smaller under the influence of progressive practice. This is due to the fact that the thresholds, the values which limit this interval, tend more nearly to approach one another. The influence is not evenly exerted upon the two thresholds, however. The

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[1] S. W. Fernberger, On the Relation of the Methods of Just Perceptible Differences and Constant Stimuli, *Psychol. Monog.*, XIV, No. 4 (Whole No. 61), 1913, 19-46.

[2] F. M. Urban, Der Einfluss der Uebung bei Gewichtsversuchen, *Arch. f. d. ges. Psychol.*, XXIX, 1913, 271-311.

threshold in the direction of decrease remains relatively constant; the threshold in the direction of increase, on the other hand, tends to become smaller. Inasmuch as this change of the size of the threshold values is greatest for the upper threshold, there is also a change in the size of the point of subjective equality. This value tends to become smaller during the later stages of progressive practice. Urban also points out that the rate of change corresponds rather closely to the law of mass-action in chemistry. Hence the rate of improvement due to the practice obtained during a given interval is dependent not only upon the work performed during that interval but also upon the state of practice of the individual at the beginning of the interval.

Urban studied, therefore, the effect of progressive practice in lifted weight experiments during an extended series of judgments. We believed that it was of advantage to obtain a clearer picture of the improvement during the initial stages of progressive practice.

Our materials and methods were similar to those employed by Urban. Small brass cylinders were used as stimuli, which were arranged in pairs. Five such pairs were employed, each consisting of a standard stimulus of 100 grams and a comparison stimulus of 88, 92, 96, 100 or 104 grams. These stimuli were placed about the circumference of a table with a revolving top so that the stimuli could be brought successively directly under the hand of the subject. Thus the space errors were eliminated. The time errors were present in the first order, i. e., the standard stimulus was always lifted first. The rate of lifting was regulated by the beats of a metronome so that the time-error remained constant. Immediately after the lifting of each comparison weight a judgment was given verbally in terms of the second weight, the subject employing the three categories of lighter, equal and heavier, which were defined in the usual manner. The observed relative frequencies of the different categories upon each of our comparison pairs thus obtained were treated in accordance with the methods of calculation developed by Urban.[3]

With these materials and with this manner of presentation, we obtained 100 judgments upon each of the 5 comparison

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[3] For a more detailed description of the stimuli, the method of lifting and the treatment of results, cf. Fernberger, ibid, 6-11; S. W. Fernberger, On the Elimination of the Two Extreme Intensities of the Comparison Stimuli in the Method of Constant Stimuli, *Psychol. Rev.,* XXI, 1914, 337-340; F. M. Urban, Hilfstabellen für die Konstanzmethode, *Arch. f. d. ges. Psychol.,* XXIV, 1912, 236-243.

pairs from each of ten naive subjects.[4] The experiments were divided into two sessions of one hour each. At the beginning of the first session we explained the manner of lifting and then gave the subject practice in making the hand-movements in time to the metronome and in grasping and lifting a single weight. Not until these hand-movements had become reasonably regular did we begin our series; and all of the judgments given after the first round or two of the table were recorded. After this preliminary instruction and practice in the hand-movements, we succeeded in obtaining 50 judgments on each of our comparison pairs from the subject during the first session. At a later session, after an interval of at least twenty-four hours, we obtained 50 more judgments from the subject upon each of our comparison pairs. Frequent rest-periods were introduced in order to eliminate the fatigue factor.

For purposes of comparison, we have divided these hundred judgments on each pair into four groups of 25 judgments each in the order in which they were taken. Hence Series 1 comprises the values of the first 25 judgments on each comparison pair; Series 2 the second 25; Series 3 the third 25; and Series 4 the fourth 25 judgments. The time of experimentation was relatively short, but the calculations involved were rather long and involved the calculation, in all, of 120 different threshold values.

The results of these calculations for the different subjects are found in Tables I-X, each table being given to the results obtained from a single subject. Table XI gives the averages of the results of all ten subjects. All of the tables show a similar arrangement. The first column contains the numbers of the series, *i. e.*, the groups of 25 judgments upon each comparison stimulus in the order in which they were taken. The second and third columns contain the values of h_1 and h_2, the coefficients of precision of the curves of the psychometric functions for the lighter and heavier judgments respectively. The next two columns labelled D and I give the values of the lower and upper thresholds respectively. The next column gives the value of the interval of uncertainty $(I-D)$. It will

be remembered that one-half of this interval is the Threshold
of Volkmann, which is recognized as the measure of sensi-
tivity of the subject. Finally, the last column contains the
values of the point of subjective equality. In each row will
be found the values obtained from a treatment of the relative
frequencies of the series indicated in the first column.

TABLE I

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.09796	0.12864	94.75	98.14	3.39	96.44
2	0.07414	0.07522	95.96	98.02	2.06	96.99
3	0.10454	0.09420	93.13	97.70	4.57	95.42
4	0.12952	0.13644	92.74	95.63	2.89	94.18

TABLE II

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.10777	0.10272	90.62	98.33	7.71	94.48
2	0.09352	0.12143	92.90	97.27	4.37	95.08
3	0.09582	0.11228	91.53	98.44	6.91	94.98
4	0.11875	0.10686	92.56	98.05	5.49	95.30

TABLE III

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.07063	0.08034	92.81	99.10	6.29	95.96
2	0.09471	0.07772	94.93	99.86	4.93	97.40
3	0.08161	0.09972	93.74	97.62	3.88	95.68
4	0.10392	0.09989	94.67	98.41	3.74	96.54

TABLE IV

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.12776	0.13971	96.86	99.79	2.93	98.32
2	0.12348	0.15051	98.64	100.69	2.05	99.66
3	0.14540	0.12635	96.30	99.10	2.80	97.70
4	0.12479	0.13280	96.22	98.16	1.94	97.19

TABLE V

Series	h_1	h_2	D	I	Interval of uncertainty	Point oj subjective equality
1	0.04786	0.08470	90.37	102.18	11.81	96.28
2	0.10187	0.11359	91.02	99.62	8.60	95.32
3	0.12352	0.12159	91.90	100.30	8.40	96.10
4	0.11625	0.09344	91.62	100.96	9.34	96.29

TABLE VI

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.12524	0.11658	93.64	96.26	2.62	94.95
2	0.10684	0.12601	93.18	96.64	3.46	94.91
3	0.15475	0.10886	92.41	96.31	3.90	94.36
4	0.14100	0.11280	93.32	95.66	2.34	94.49

TABLE VII

Series	h_1	h_2	D	I	Interval oj uncertainty	Point of subjective equality
1	0.07108	0.07576	91.93	99.16	7.23	95.54
2	0.07554	0.09222	92.17	97.37	5.20	94.77
3	0.08500	0.08015	92.13	98.98	6.85	95.56
4	0.09400	0.08321	92.17	98.26	6.09	95.22

TABLE VIII

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.09365	0.11546	92.69	105.56	12.87	99.12
2	0.13934	0.09797	90.85	104.55	13.70	97.70
3	0.11675	0.12700	90.86	102.52	11.66	96.69
4	0.08441	0.10144	90.67	101.99	11.32	96.33

TABLE IX

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.09038	0.08279	88.13	100.43	12.32	94.29
2	0.06068	0.12156	90.84	98.76	7.92	94.80
3	0.07990	0.09621	91.71	99.01	7.30	95.36
4	0.11394	0.14412	92.76	98.48	5.72	95.62

TABLE X

Series	h_1	h_2	D	I	Interval of uncertainty	Point of subjective equality
1	0.05983	0.07900	93.22	105.08	11.86	99.15
2	0.10953	0.09884	94.49	101.79	7.30	98.14
3	0.11907	0.09212	94.36	101.67	7.31	98.02
4	0.12128	0.08246	93.83	99.99	3.08	96.91

TABLE XI

Series	h_1	h_2	D	I	Interval oJ uncertainty	Point oJ subjective equality
1	0.08922	0.10058	92.50	100.40	7.90	96.45
2	0.09796	0.10751	93.50	99.46	5.96	96.48
3	0.11064	0.10585	92.81	99.16	6.36	95.99
4	0.11479	0.10935	93.06	98.56	5.50	95.81

An examination of the values contained in Table XI indicates that the same tendencies are present for our series as were found by Urban, only these tendencies are even more marked. The values of h_1 (the coefficient of precision for the lighter judgments) show a steady rise and one which is more marked for the early series than for the later. The values of h_2 (the coefficient of precision of the heavier judgments) show a marked tendency to increase especially for the earlier series. The curve does not rise steadily, however, inasmuch as the value for the third series is slightly smaller than that for the second. The values of the threshold in the direction of decrease (D) remain fairly constant. They show variations of an unsystematic character such as one usually finds in lifted weight experiments, but no systematic tendency is evident. The values of the threshold in the direction of increase (I), on the other hand, show a marked tendency to decrease which again is most marked between the first and second series. The values of the |interval of uncertainty show a marked tendency to decrease, particularly marked at first. This decrease is broken at one point; the value for the third series being slightly larger than that for the second series. The values for the point of subjective equality similarly show a tendency to decrease, but not so markedly as for some of the other values. This tendency is broken at one point; the value for the second series being very slightly larger than that for the first.

Our results, then, are precisely similar to those obtained by Urban, except that the tendencies indicated are here more marked. This we would expect, since we are dealing with the initial stages of progressive practice, while Urban was dealing with the effects of progressive practice for an extended series of experiments. In our results the course of the general tendencies to increase or decrease are broken in only three places; the value of h_2 for the third series, the value of the interval of uncertainty for the third series, and the value of the point of subjective equality for the second series. Regarding this last value we can only say that the effect of the initial practice is about equally strong upon both thresholds; that at the first the lower threshold tends to assume a slightly greater value to about the same extent that the value of the upper threshold is decreased. Hence as the two thresholds approach each other in approximately the same amount, the point of subjective equality remains practically unchanged.

The other two apparently anomalous values are more read-

ily explained, and indeed, strengthen our belief that pro-
gressive practice is the sole factor which is operating here.
Progressive practice is essentially a form of learning process.
In the case of any learning process there is always something
of a loss, due to forgetting during a rest-period, so that in
starting out after the rest the subject does not have as high
a degree of efficiency as he had at the end of the work-period
just before. It will be remembered that we obtained the first
two groups of 25 judgments on each comparison pair during
the first day's experimentation for each subject, and the last
two groups during a second experimental period. Hence there
was a rest-period of more than one day between the second
and third groups. During this period some of the practice
obtained during the first period, we may well believe, was
lost, so that, for the third group the subjects started at a lower
degree of efficiency than they had had at the ending of the
second group. This, indeed, is reflected throughout the re-
sults and shows particularly in the two apparently anomalous
values of the h_2 and the interval of uncertainty of the third
series, which are slightly lower and higher, respectively, than
the corresponding values of the second group.

Although we have this exceedingly great regularity of the
different tendencies of increase and decrease for the different
values under consideration for the averages of all ten sub-
jects, still the values for the individual subjects do not show
quite such great regularity. Nevertheless the values for
every subject show more or less markedly the same general
tendencies of increase and decrease of the different values.
The values for one subject (Table X) show practically a
regular increase and decrease in values with one exception;
the values of the interval of uncertainty for the second and
third groups are practically identical. One would not expect
great regularity in the values of the individual subjects, be-
cause relative frequencies from 25 judgments on each com-
parison pair are far too small a number to be considered
ideally as probabilities. Still we were forced to use such a
small number for purposes of comparison if we wished to
study the initial effects of progressive practice. We believe
that much greater reliance is to be placed upon the averages
for all of the subjects as in this case accidental variations
would tend to cancel one another.

The fact that progressive practice in its initial stages has
such a marked effect upon the position of the thresholds and
upon the values of the interval of uncertainty and the point
of subjective equality is of exceedingly great significance in

the application of the psychophysical methods for purposes of anthropometric measurements. Anthropometrists seek to determine the sensitivity of the subjects or the point of subjective equality with as few a number of judgments and in as short a time as possible. The method of constant stimuli recommends itself for such measurements inasmuch as it is by this method alone that the subject can be kept in entire ignorance of the objective relations of the stimuli. The calculations involved by the use of the method of constant stimuli are rather lengthy unless the results are taken in such a form that one may apply Urban's tables, referred to above. One of the conditions for the application of these tables is that the number of judgments obtained must be exactly divisible into 100. Hence we may employ the tables only in those cases where we have obtained either 10, 25, 50 or 100 judgments upon each comparison pair. In order to show the effect of this initial practice upon the number of determinations obtained, we have calculated the intervals of uncertainty and the points of subjective equality for each of our ten subjects for the first 25, the first 50, and the first 100 judgments on each of our comparison pairs. The first values obviously correspond to the first rows of Tables I-X. The second values are calculated from the observed relative frequencies of groups 1 and 2 of the former tables. The last values are calculated from the relative frequencies of all of the determinations made, namely, groups 1, 2, 3 and 4.

TABLE XII

Subjects	Interval of uncertainty			Point of subjective equality		
	25	50	100	25	50	100
A	3.39	2.84	3.50	96.44	96.31	95.61
B	7.71	6.66	6.35	94.48	94.81	95.02
C	6.29	5.57	4.76	95.96	96.70	96.35
D	2.93	2.27	2.48	98.32	98.86	98.35
E	11.81	9.60	9.04	96.28	96.02	96.19
F	2.62	2.69	3.12	94.95	95.10	94.76
G	7.23	6.08	6.47	95.54	95.17	94.70
H	12.87	13.81	12.96	99.12	98.40	97.20
I	12.32	10.19	8.31	94.29	94.60	95.18
J	11.86	9.23	7.87	99.15	98.62	98.02
Average	7.90	6.89	6.49	96.45	96.46	96.14

The values obtained from this calculation are given in Table XII. The first column contains the letters of the subjects. The next three columns contain the values of the interval of uncertainty,—the first of these, those for the first 25 judgments on each comparison pair, the next for the group of 50 judgments and the third for the group of 100 judgments. The next three columns show a similar arrangement as regards the groups and contain the values of the point of subjective equality. The last row of values in this table contains the averages for each column. If we consider the averages for the point of subjective equality, we find that the values for the group of 25 judgments is almost identical to that for the group of 50 judgments. Both vary slightly from the value for the entire group of 100 judgments. But the variations are so slight that we may consider them to be negligible and dismiss the point of subjective equality from our discussion.

A very different state of affairs is to be found when we compare the averages for all of our subjects of the intervals of uncertainty for the different groups. If we compare the group of 100 judgments with the group of the first 50 judgments, we find that the value for the latter is somewhat larger, the difference being just 0.4 grams. The difference between the values for the group of 100 judgments and the group of the first 25 judgments is considerably larger, being 1.41 grams, or over three and a half times as large as the difference between the values of the 100 and 50 judgment groups.

Now, in anthropometric measurements we have two ideals to which we must more or less closely conform—time and accuracy. We cannot actually conform to the ideal of accuracy because it was shown by our results and those of Urban that this factor of progressive practice may be observed up to the 4th-6th group of 100 judgments. In making anthropometric measurements one cannot take so many reactions from a single individual as this would outrage the principle of the time required to obtain the judgments.

On the other hand, the small number of determinations advocated by certain writers is obviously too small. Whipple,[5] for instance, advocates the taking of only 10 determinations; but in the light of our findings such a procedure may furnish an exceedingly uncertain and inaccurate measurement of the sensitivity of the individual. If the interval of uncertainty is so much larger for a group of 25 judgments upon each

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[5] G. M. Whipple, *Manual of Mental and Physical Tests.* Baltimore, 1910, 188-193.

comparison pair than that for 100 judgments, we must certainly conclude that any procedure which employs less than 25 judgments is mischievous and inadmissible.

The anthropometrist finds himself between Scylla and Charybdis; if he makes a large number of determinations he sacrifices more time than is ordinarily at his disposal, and if he makes a small number of determinations his results are inaccurate and valueless. And in his extremity he may very pertinently inquire: What is the least number of determinations upon which the measurement of an individual's sensitivity may safely be based? In the light of our findings it would appear that 50 determinations upon each comparison pair is the smallest number upon which an accurate measurement can be based. We have also found that an average subject may be taught the technique of lifting and also that we may obtain 50 judgments on each comparison pair by our methods within a single session of an hour's duration. This includes frequent and sufficient rest-periods. This arrangement, furthermore, has the advantage in that the subject is not kept too long at the task; and on the other hand, may be disposed of in a single session. We believe that an hour for the determination of the sensitivity of each subject is not too much to ask from either the anthropometrist or the clinician. Indeed, our results show that he must spend this time if he is going to employ lifted weight experiments to obtain results which will have an admissible degree of accuracy.

Obviously it is well to obtain as many judgments as possible, because the greater the number of judgments the greater will be the accuracy of the determinations. But in anthropometric measurements, the time required for the obtaining of the results is an important factor, and hence one is impelled to set arbitrary limits as a sort of compromise between accuracy and time. We suggest, on the basis of our results, that 50 judgments upon each of 5 comparison pairs is a sufficient number to require from each subject for the ordinary anthropometric study. Our results show that the values obtained do not vary greatly from those obtained from a group of the first 100 judgments. The first 50 judgments upon each pair of stimuli may be obtained within the space of one hour's sitting, including the preliminary practice in the technique of lifting. We do insist that no determination of less than 50 judgments upon each comparison pair is admissible inasmuch as the results obtained violate the principle of accuracy. The divergences in the results are due to the effect of the progressive practice obtained by the subject during the experi-

mentation. The effect of this progressive practice is to increase the values of the coefficients of precision and to decrease the size of the values of both the interval of uncertainty and to a less degree of the point of subjective equality. The effects of this progressive practice are stronger at the beginning of the experimental series and decrease at first rapidly and then more slowly as the experimentation continues.